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SILICON SOLAR CELL PROCESS DEVELOPMENT, FABRICATION, AND ANALYSIS

THIRTEENTH QUARTERLY REPORT

FOR PERIOD COVERING

1 MARCH 1983 THRU 30 JUNE 1983

D.C. Leung and P.A. Iles

JPL CONTRACT NO. 955089

OPTICAL COATING LABORATORY, INC.
Photoelectronics Division
15251 E. Don Julian Road
City of Industry, California 91746

"The JPL Low-Cost Silicon Solar Array Project is sponsored by the U.S. Government of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE."

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ABSTRACT

In this reporting period, measurements of minority carrier diffusion lengths were made on the small mesa diodes from HEM Si and SILSO Si. The results were consistent with previous Voc and Isc measurements. Only the medium grain SILSO had a distinct advantage for the non-grain boundary diodes. Substantial variations were observed for the HEM ingot 4141C. Also a quantitatively scaled light spot scan was being developed for localized diffusion length measurements in polycrystalline silicon solar cells. A change to a more monochromatic input for the light spot scan results in greater sensitivity and in principle, quantitative measurement of local material qualities is now possible.

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I. INTRODUCTION

The objective of this program is to study and compare various unconventional silicon sheets, to understand the mechanisms that limit the efficiency of solar cells from these materials and to correlate variations in growth parameters and performance of solar cells.

In this reporting period, additional supporting measurements of minority carrier diffusion lengths were made on the small diodes in large slices of HEM Si (Crystal Systems) and SILSO Si (Wacker). Also a quantitatively scaled light spot scan was being developed for localized diffusion length studies in polycrystalline silicon solar cells.

II. TECHNICAL DISCUSSION

A. Minority Carrier Diffusion Lengths Of Small Diodes On HEM And SILSO Materials

In order to continue the work of last quarter on small diodes made from both the HEM and SILSO materials (see the 12th Quarterly Report), minority carrier diffusion lengths were measured on selected diodes of both materials. The diodes were selected to include good, intermediate and bad samples. The results of the measurements are listed in Table 1. From Table 1, only the medium grain portion of the SILSO material shows a distinct difference between the grain boundary and non-grain boundary diodes. For both the long grain portion of SILSO, and HEM ingot 4141C, the non-grain boundary diodes have higher values, but do not show distinct advantage overall. These results are not inconsistent with previous results as recorded in the 12th Quarterly, even though the previous results of Voc and Isc were more distinct, probably because of sizes of sampling.

Again, the variations of diodes in HEM ingot 4141C implied variations in material quality in the ingot. As concluded from the 12th Quarterly, more refined techniques such as light spot scan will give more detailed results.

TABLE 1

MINORITY CARRIER DIFFUSION LENGTH OF SELECTED SILSO & HEM DIODES

	DIODES NUMBER	L_D(UM)FOR GRAIN BOUNDARY DIODES	DIODES NUMBER	L_D(UM)FOR NON-GRAIN BOUNDARY DIODES
SILSO (LONG GRAIN)	1 3 5	24 25 17	2 4 6	25 12 37
SILSO (MED. GRAIN)	7 9 11	22 19 16	8 10 12	58 45 48
SILSO (FINE GRAIN)	13	17		
HEM	1 3 5 7	45 82 78 90	2 4 6 8	47 108 62 34
CZ			1	183

B. **Modified Light Spot Scan System**

In this contract, there has always been light spot scan measurements made (see Appendix V C of the Phase I Annual Report). Figure 1 shows the schematic of the system. The filter used was a thin silicon film the transmission of which is shown in Figure 2. The purpose of the filter was to cut down the shorter wavelength spectrum of the incoming light so that the response of cells from different material qualities would be distinct and representative of the bulk behavior. Throughout the contract, the system has been successfully used for qualitative measurements. However, in order to obtain quantitative results, it is not convenient to use the existing Si film filter because of broad transmission spectrum as shown in Figure 2. On the other hand, the response of a monochromatic input could be easily calibrated as a function of diffusion length because the mathematical model has been derived (see Reference 1). This monochromatic light spot scan had been adapted for material studies in many places. To a first approximation, the response of long wavelength monochromatic input Sout is proportional to

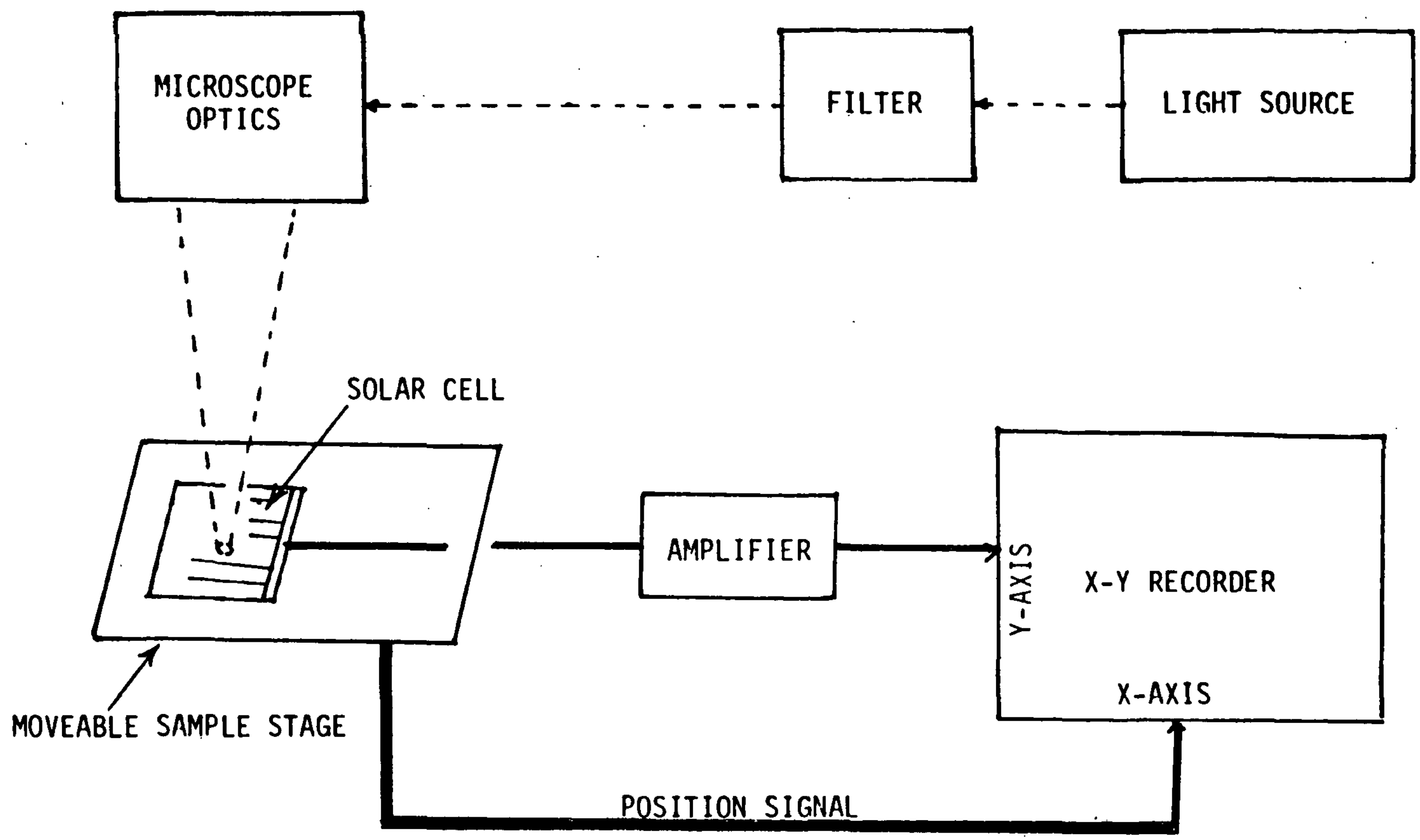
$$\frac{\alpha L}{\alpha L + 1} \qquad (1)$$

$$\text{i.e} \quad Sout = K\left(\frac{\alpha L}{\alpha L+1}\right) \qquad (1)$$

Using absorption coefficients from Dash & Newman (Reference 2), equation 1 is plotted in Figure 3 for two absorption coefficients corresponding to two wavelengths. It is obvious that at longer wavelength the function is more "linear" and therefore has better overall sensitivity. However, the response of the Si solar cell could drop down quickly for wavelengths approaching the energy band edge. In order to maintain a reasonable signal level with the existing light source, a wavelength of 970nm was chosen. It was obtained by using a narrow band interference filter centered on this wavelength with a half band width of 10nm. This filter reduced the signal level by about 97%, (compared to a

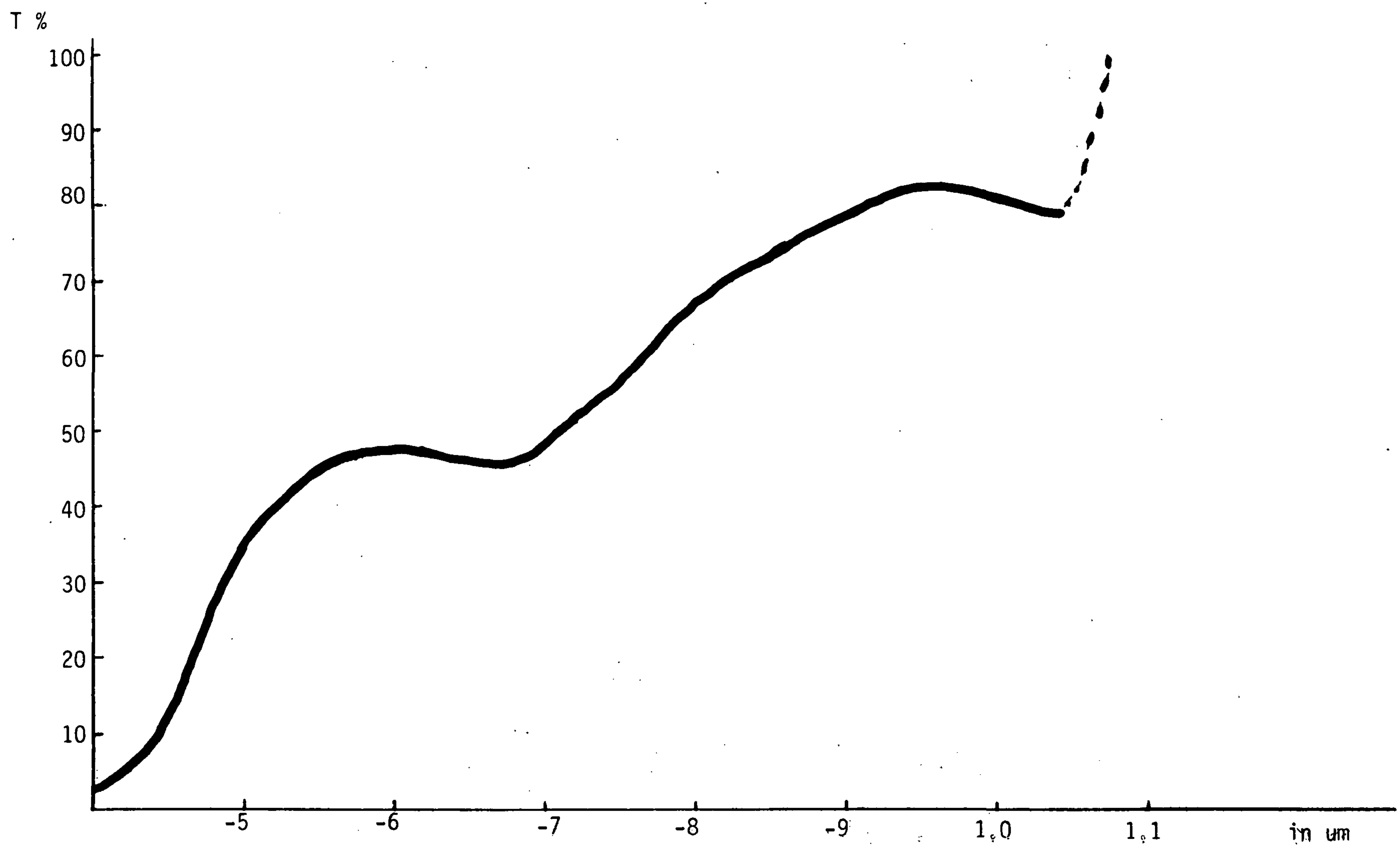
reduction of around 1/3 from the thin film Si filter). Nevertheless, the new signal/noise ratio is adequate and good measurements can be made.

Careful calibration for scaling the diffusion length vs. the response was achieved, using cells with known diffusion length, measured by the SPV method and some preliminary scans were made. However, between the end of this reporting period and the time of writing this report, the calibration was revised by using a different set of absorption coefficients. which is more representative of Si in this wavelength range. The modified calibration will be discussed in detail in the next report. Figure 4 shows a comparison of two scans with their signal amplified to similar levels on the same portion of a sample. It can be seen that the scan with the monochromatic input has higher sensitivity to local variation than the scan using the thin film Si filter. Therefore even without a scale, the monochromatic input shows a marked improvement.



A BLOCK DIAGRAM OF A FINE LIGHT SPOT SCANNING APPARATUS

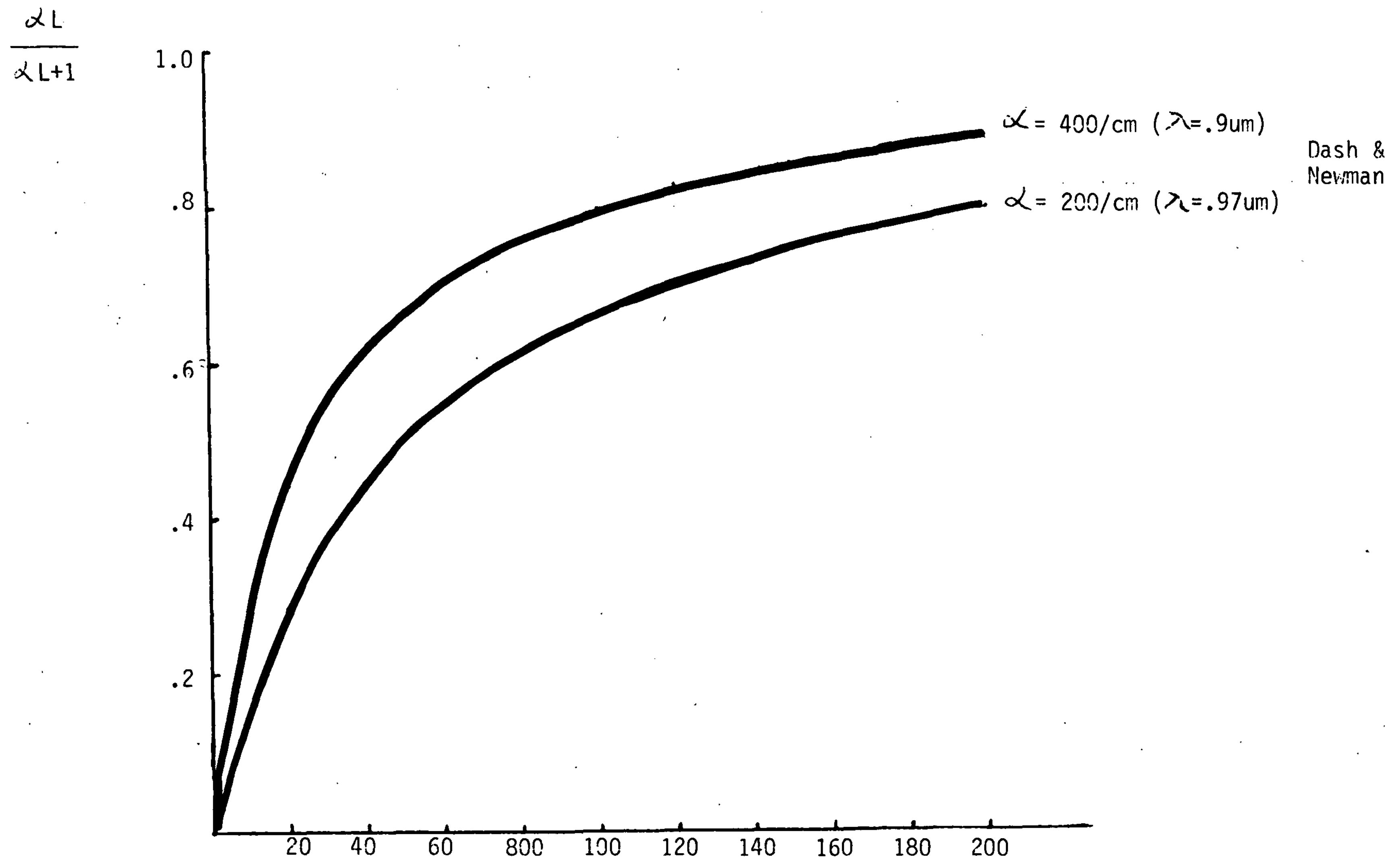
FIGURE 1



WAVELENGTH

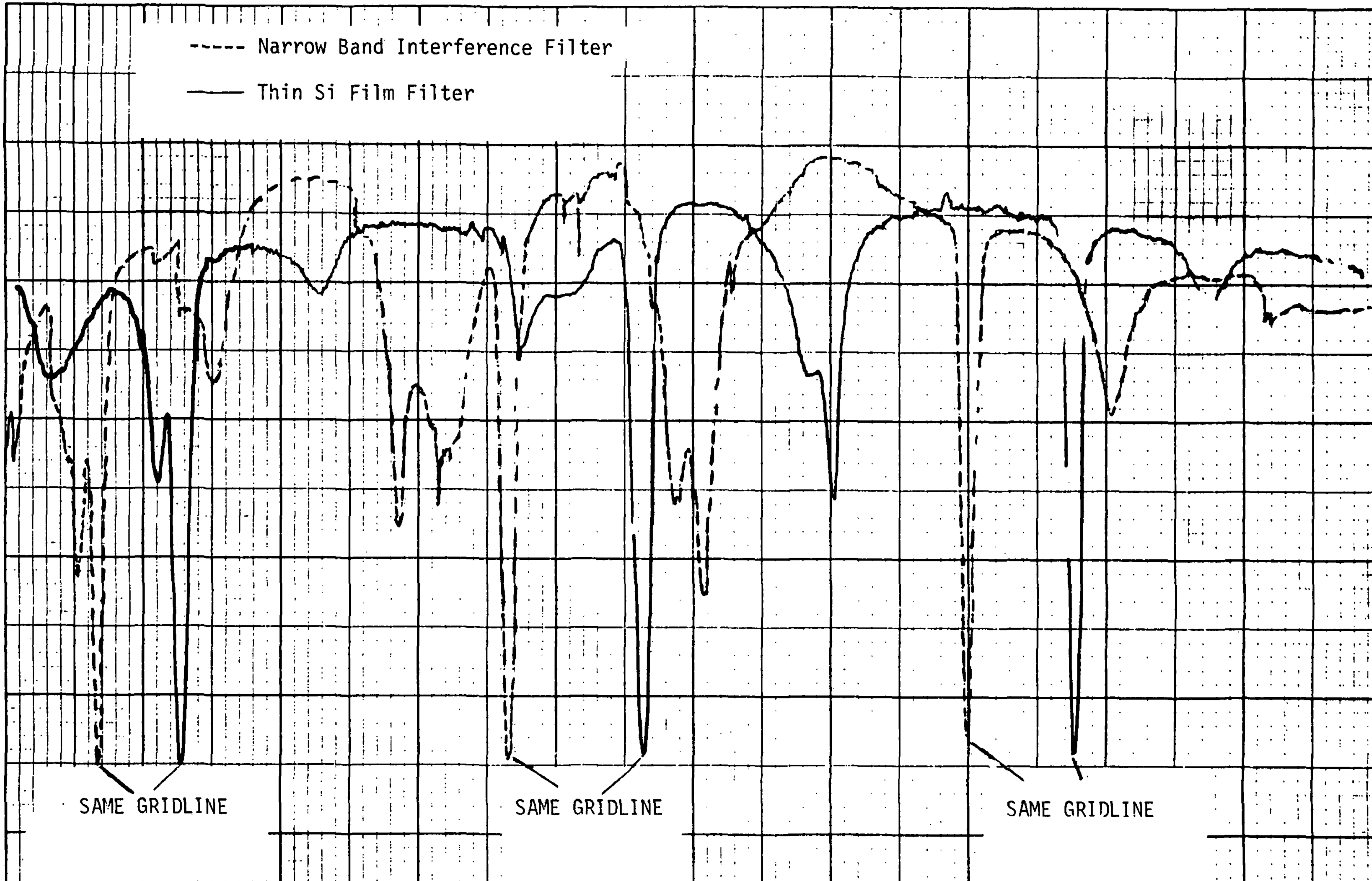
TRANSMISSION OF A THIN Si FILM FILTER

FIGURE 2



CALCULATED MONOCHROMATIC RESPONSE FOR TWO DIFFERENT VALUES OF ABSORPTION COEFFICIENT AS A FUNCTION OF DIFFUSION LENGTH

FIGURE 3



COMPARISON OF LIGHT SPOT SCANS OF THE TWO DIFFERENT FILTERS

FIGURE 4

III. CONCLUSION

Small Diodes Of HEM And SILSO

Results from supporting measurements of diffusion length for small diodes were consistent with previous Voc and Isc measurements. Only the medium grain SILSO had a distinct advantage for the non-grain boundary diodes. Substantial variations were observed for the HEM ingot 4141C.

Modified Light Spot Scan System

A change to a more monochromatic input for the light spot scan resulted in greater sensitivity and in principle, quantitative measurement of local material qualities is now possible.

IV. WORK PLANNED

To calibrate and verify the modified light spot scan system for quantitative measurements and to apply the measurements to various sheet materials, and to evaluate the localized differences in these materials.

V. REFERENCES

1. H. Hovel, "Solar Cells", Semiconductors and Semimetals, Vol. 11, Academic Press, 1975.

2. Dash & Newman, Phys. Rev. 99, 1151 (1955).

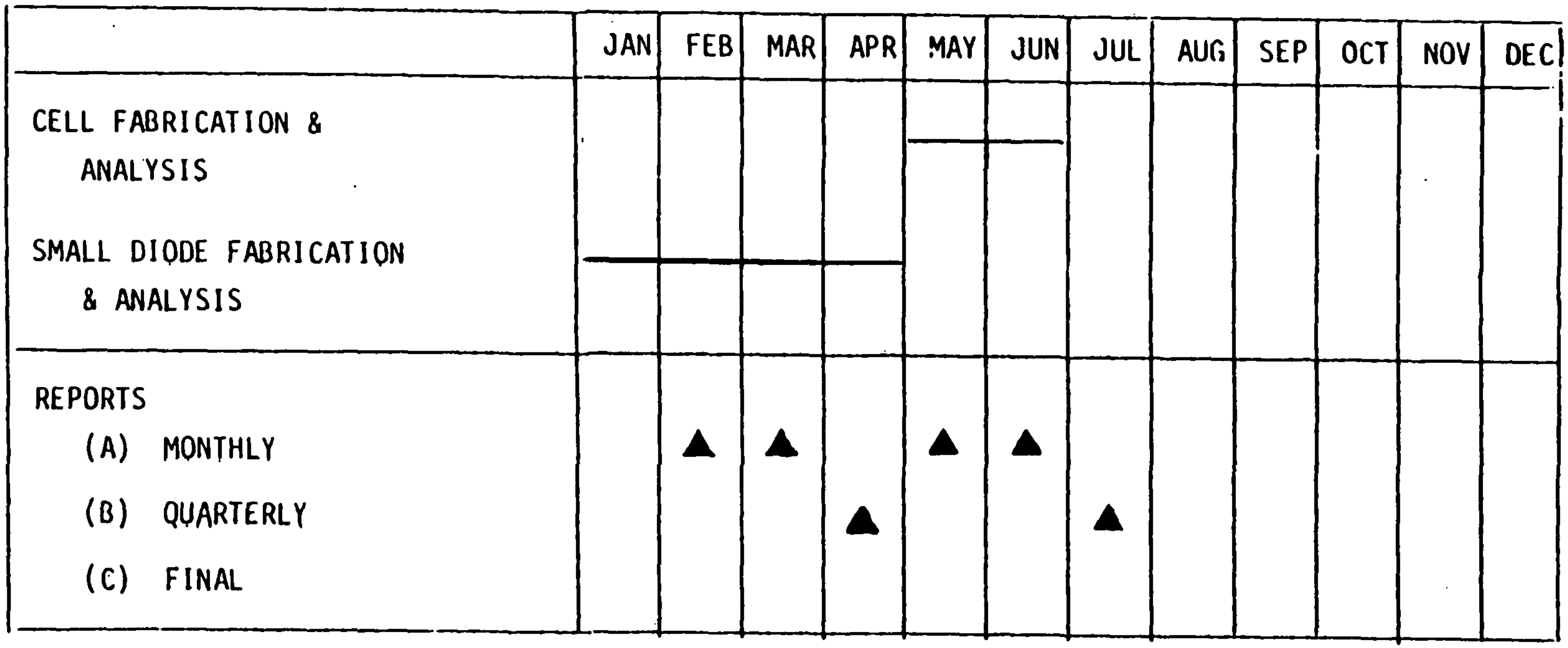
APPENDIX I

ABBREVIATIONS

V_{OC}:	Open Circuit Voltage
I_{SC}:	Short Circuit Current
J_{SC}:	Short Circuit Current Density
I_{SCR}:	Short Circuit Current (Red Response) at Wavelength Above ~.6um
I_{SCB}:	Short Circuit Current (Blue Response) at Wavelength Below ~.6um
CFF:	Curve Fill Factor
η :	Solar Cell Conversion Efficiency
L:	Minority Carrier Diffusion Length (D.L.)
I_{MAX}:	Current at Maximum Power Point
V_{MAX}:	Voltage at Maximum Power Point
BSF:	Back Surface Field
BSR:	Back Surface Reflector
V_B:	Bias Voltage
I_o:	Diode Saturation Current
HEM:	Heat Exchanger Method
EFG:	Edge Defined Film-Fed Growth
SOC:	Silicon on Ceramic
RTR:	Ribbon-to-Ribbon
UCP:	Ubiquitous Crystallization Process
SPV:	Surface Photovoltage
MLAR:	Multi-Layer Anti-Reflective
R_s:	Series Resistance

APPENDIX II

TIME SCHEDULE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